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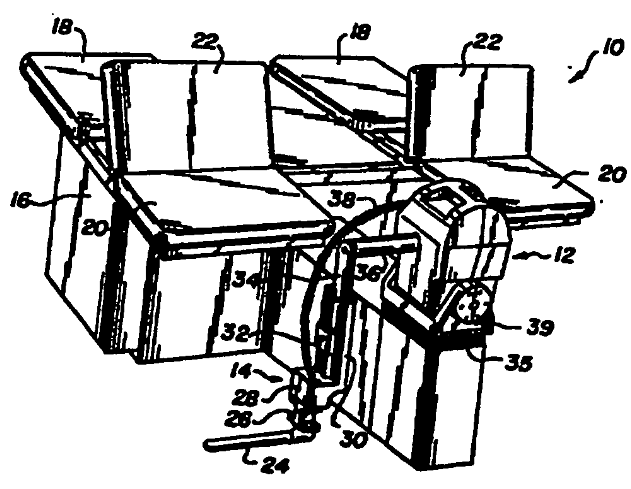
(71) Applicant: McArthur, Jim, 1760, Kingsway Avenue, Port Coquitlam British Colombia V3C 1S5 (CA)

(72) Inventor: McArthur, Jim, 1760, Kingsway Avenue, Port Coquitlam British Colombia V3C 1S5 (CA)

(74) Representative: Tillbrook, Christopher John, c/o Reginald W. Barker & Co. 13, Charterhouse Square, London EC1M 6BA (GB)

(54) **Multi-mode exercising apparatus.**

(57) A multi-mode exercising apparatus, which includes an exercising member (14), a rotary actuator (65) coupled to the exercising member (14) controlling its movement in response to fluid flow therethrough and a servo-valve means (78) coupled to the actuator (65) for controlling both the direction and rate of fluid flow through the actuator (65) in response to an input electrical signal. A hydraulic pump (112) is used for pressurizing the fluid and a motor means (114) for driving the pump (112). The hydraulic fluid is stored in a reservoir (110). Means are provided for monitoring the angular position of the actuator (65) and a load cell means (26) coupled to the member provides a signal proportional to the magnitude of force applied directly to the member (14). A microprocessing means (126) is used for controlling the input electrical signal to the servo valve (78) in response to the signal of the load cell, the angular position of the actuator (65), program means stored in the microprocessor (126) and calibration data.



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BACKGROUND OF THE INVENTION

The present invention relates to a multi-mode exercising apparatus for providing exercise in isometric, isotonic, isokinetic and constant power modes.

In isometric exercises the rate of angular change or velocity of the limb is zero, while the force can be in either of two directions. In an isotonic mode the load or resistive force has a constant value while the velocity varies. In an isokinetic mode the force is allowed to vary to match the user's force in such a way that the velocity is kept constant. Finally, in a constant power mode both velocity and force are allowed to vary such that their product is kept constant. In any of the latter three modes a muscle may undergo either a concentric contraction in which the muscle is developing force while it is shortening in length, or an eccentric contraction in which the muscle is developing force while it is increasing in length. By way of example, in a concentric stroke the user moves the arm or limb of the exercising machine while in an eccentric stroke the arm attempts to move the limb of the user.

Exercise apparatus exists which provide a constant force load by means of weighted plates or springs over the whole range of movement of the limb. Since the muscle is generally strongest over a relatively narrow range of such movement, fixed load or constant force devices do not optimally load a muscle through its entire range of movement. A device which does load a

disclosed in U.S. Patent No. 3,465,592, issued to Perrine on September 9, 1969. The Perrine device employs a hydraulic piston-cylinder in combination with a constant flow valve and an associated valving system to provide a constant flow through one side or the other of the hydraulic piston-cylinder. A pressure valve measuring fluid pressure is used to measure user applied force. Perrine also discloses an alternative embodiment employing an electric motor and a gearing system and clutches to couple user torque to worm gear being rotated by the motor at a constant velocity. The latter device is restricted to either an isometric or an approximate constant velocity mode and to concentric exercises. Moreover, the Perrine device does not include in its measurement of the force the weight of the handle and arm linkage or resistance caused by friction.

U.S. Patent No. 3,784,194, issued January 8, 1974, to Perrine discloses the use of a fluid operated actuator in combination with a system of overlapping valve holes for setting the rate of fluid flow and consequent velocity. The latter device again is restricted to an approximate constant velocity mode and is subject to the other limitations expressed in connection with the above-mentioned earlier Perrine patent.

SUMMARY OF THE INVENTION

According to the invention there is provided a multi-mode exercising apparatus including an exercising member and a rotary actuator coupled to the exercising

member for controlling movement of the member in response to fluid flow therethrough. Coupled to the actuator is a servo valve means which controls fluid flow through the actuator in response to an unput electrical signal. A hydraulic pump operated by motor means is used to pressurize hydraulic fluid which is stored in a reservoir. Means are provided for monitoring the angular position of the actuator while a load cell means coupled to the member provides a signal proportional to the magnitude of force supplied directly to the member. Microprocessor means are used for controlling the input electrical signal to the servo valve in response to the signal from the load cell, the angular position of the actuator, program means stored in the microprocessor and calibration data.

By utilizing a servo valve means highly accurate control of the fluid flow into the actuator is possible by simply controlling the level of input current to the servo valve means. Moreover, utilization of a load cell proximate the point of application of the user force provides an accurate direct measure of the user applied force independently of any contribution due to weight of the linkage or friction in the linkage. By utilizing a microprocessor a wide variety of modes of operation of the actuator are pssible, together with the implementation of a large number of safety checks.

Conveniently, the dump valve can be used for shunting fluid flow out of the hydraulic pump in the event

member is desired.

Advantageously, a limit switch means may be used to control the power applied to the motor means in response to rotation of the actuator to preselected limits of rotation.

Preferably, the means for monitoring the angular position of the actuator is an optical shaft encoder for providing signals indicative of the angular velocity, position and direction of rotation of the actuator. Means may also be provided for sensing the actuator fluid pressure in order to provide a signal proportional to the torque applied to the actuator by the member.

Conveniently, a dump valve switch means can be employed to control power applied to the dump valve. A manually operable over-ride switch means may be incorporated to control power to the motor means.

A microprocessor means may also be used for controlling operation of the dump valve switch means and power applied to the motor means in response to program means stored in the microprocessor and input data, including calibration data, actuator fluid pressure levels, signals from the optical shaft encoder, signals from the load cell means, the motor sensing means, the dump valve sensing means and the condition of the limit switch means.

The exercising apparatus referred to above is capable of operating in response to instructions from the computer and input data in any of the four basic exercise modes through selectable angles of rotation and

with selectable amounts of force. The apparatus may also be employed in either a concentric or an eccentric force condition. By sensing motor and dump valve power levels, actuator pressure levels and load cell voltage levels, a sophisticated set of redundant safety checks may be constantly effected by the microprocessor means in addition to hardware controlled safety measures to provide a high level of safety and flexibility combined with significantly improved accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings representing a preferred embodiment of the invention,

Figure 1 is a perspective view of the exercising apparatus without the microprocessor,

Figure 2 is an exploded view of the handle attachment,

Figure 3 is a front elevation view of the actuator assembly with the casing removed,

Figure 4 is a side elevation view of the actuator assembly shown in Figure 3,

Figure 5 is a view of the actuator assembly tilted from the position shown in Figure 3, and

Figure 6 is a schematic diagram of the control elemets of the exercising apparatus.

DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

The user station 10 of the exercising apparatus shown in Figure 1 consists of an actuator assembly 12 having an actuator shaft 60 (see Figure 3) to which is attached an exercising member 14. A housing 16

enclosing a hydraulic pump and heat exchanger (not shown) also supports a set of cushions 18, 20 and 22 adjacent each side of the actuator assembly 12. The central cushion 22 of each set of cusions is positionable in selectable reclined positions from a fully flat position to an upright position. The actuator assembly 12 is movable in a vertical position by a track mechanism located below the actuator assembly 12 (not shown) and attached to a U-shaped base 39. The bellows 35 encloses a portion of the sliding track assembly. The actuator assembly 12 is also rotatable around a shaft and bearing assembly 40, located at either end of a base 39.

Exercising member 14 consists of shaft 36 affixed to an actuator shaft 60 splined at either end and shown in Figures 3 to 5. An elongated arm 34 of a rectangular cross-section, in turn, is affixed to shaft 36. A block 30, shown in part in Figure 2, slidably captures arm 34 and is lockable in selectable positions thereon by a screw and wedge element 32. Integral with block 30 is a handle mount 28 which has a recess (not shown) for receiving one end of a load cell block 26 by means of a pin slidably insertable into hole 54 in mount 28, and a hole 52 in a boss 50 on one end of the load cell block 26. A boss 44 on the other end of the load cell block 26 also has a hole 46 which aligns with a corresponding hole 48 in a handle receptacle 42 of a handle 24 to receive a locking pin (not shown). A pair of strain ... 56 and 58 each wound in a wave-length manner and

oriented orthogonally to each other are mounted on a wall 57 parallel to the axis of the bosses 50 and 44 of one of two U-shaped hose recesses of the block 26. The load cell block 26 is positioned to provide signals proportional to force applied to the handle 24 transverse to the arm 34 and to provide signals which permit cancelling out of the torque about the axis through bosses 44 and 50 and force components parallel thereto.

Cable 38 has four wires which carry electrical signals from the load cell 26. Load cell 26 is a standard unit commercially available from a number of manufacturers.

One side of the actuator assembly 12 is shown in Figure 3 with the cover removed. At the upper end of the assembly 12 is the actuator 65 having a shaft 60 at each end and a gear pulley 59 affixed thereto. The gear pulley 59 is, in turn, affixed to a cam 61 having a lower step 67 extending radially approximately 40° and an upper step slightly further removed from the centre of the actuator arm, also subtending an angle of approximately 40° from the centre of the actuator arm. Three microswitches 62, 63 and 64 are positioned around the shaft 60 and are operated by cam 61 upon rotation of the shaft 60 to predetermined angular positions. The limit switch 63 is located intermediate limit switches 62 and 64. Limit switches 62 and 64 are spaced so that they are operated by an angular sweep of the actuator of 265°.

Limit switch 62 is operated by contact upon clockwise rotation by the upper step 69 of the cam 61 while limit switch 64 is operated by contact with the upper step 69 upon counter-clockwise rotation of the cam 61. The central limit switch 63 is operated during initial calibration in order to provide a datum point for the system which allows the determination of the angular position of the member 14.

An encoder pulley 74 is coupled to gear pulley 59 by gear belt 75. Affixed to the encoder pulley shaft is an optical shaft encoder assembly consisting of an optical shaft disk 66 and a pair of light-emitting diodes and associated photo transistor detectors (not shown). The encoder disk 66 has a plurality of inner 70 and outer 68 radially spaced apart slots through which light-emitting diodes are directed. Relative radial spacing of the inner and outer slots is such that upon rotation of the disk, two signals are generated which are approximate square waves and are timed such that the edges of the pulses of each set of signals are 90° out of phase. The resultant signals generated allow the determination of both angular positions as well as direction and angular velocity of rotation of member 14.

The side view of the actuator assembly is illustrated in Figure 4 which shows the actuator 65 rotatably supported by a front plate 71 and a rear plate 73. Below the actuator 65 and coupled thereto is a servo

valve 78. Hydraulic lines 72 from a dump valve (not shown) located in housing 16 lead to the servo valve 78. The entire actuator assembly can be tilted as shown in Figure 5 about base 39 in either direction to permit rotation of the arm assembly about an axis inclined by a selectable amount to the horizontal.

The system of control of the exercising apparatus is illustrated schematically in Figure 6. Hydraulic fluid from a reservoir 110 is supplied to a hydraulic pump 112. The pump 112 is powered by a motor 114 and fluid which is pressurized by the pump 112 is directed into a dump valve 116. The dump valve 116 receives operating power from 110 VAC source through relay 150. When powered, the dump valve 116 shunts pressurized fluid into a return line 121 which directs fluid through a conventional heat exchanger 152 back to the reservoir 110.

After passing through the dump valve 116, pressurized fluid enters a servo valve 78 having a pair of outlet/inlet ports which couple to corresponding ports of the actuator 65. Fluid flows out one of the two servo valve ports into the actuator and back into the other servo valve port. Both the direction and rate of fluid flow into the actuator 65 is controlled by electrical current directed into the servo valve 78 along cable 115. The actuator 65 is coupled mechanically to an arm 34 and handle 24 as previously discussed.

The sensing signals which are used to monitor operation of the system include voltage signals from the load cell 26 conducted along lines 170 and 172 to a signal conditioner 132. The latter voltage levels are proportional to the force supplied directly to the handle 24 and do not include any contribution due to weight of the arm 34 and block 30. A pair of pressure transducers 166 and 168 supply voltage signals to the signal conditioner 132 which are proportional to the pressure levels present across the actuator 65 which levels result from the torque applied to the actuator shaft by the user through the arm 32, block 20 and handle 24.

The shaft encoder 66 produces two sets of square waves which are sent to the signal conditioner 132 along lines 162 and 164. The latter signals are indicative of actuator shaft position, angular velocity and direction of rotation.

Operation of limit switches 62 and 64 interrupt current to relay 140 causing the latter to open thereby disconnecting 110 volts AC from the coils 136 of a mechanical relay. Contact 134 of the latter relay couple a source of 220 volts AC when closed to the motor 114. A mechanical manually operated over-ride switch 146 is operable to cause the opening of relay 140 and thereby disconnecting the 220 volts AC source from motor 114. The latter switch can be used as a panic button by the user in the event there is a system failure.

The central limit switch 63 is operable to disconnect a line from the signal conditioner 132 from ground thereby resulting in a signal being generated which gives the microprocessor 126 a datum point for calibration purposes. With the latter datum point the microprocessor 126 can determine the angular position of the actuator shaft.

Operation of the dump valve is controlled by a relay 150 which, in response to signals from the signal conditioner 132 sent along line 162, close and connect 110 volts AC to the dump valve 116. The application of power to the dump valve 116 is monitored by line 163 leading to the signal conditioner 132. Normally, the application of power to 114 is sensed by line 115 leading to the signal conditioner 132. The latter two power sensing circuits both allow the microprocessor 126 to tell if its control of the motor 114 and dump valve 116 is effective or if something else is causing motor 114 and dump valve 116 not to work.

Control of the operation of the system is achieved by a microprocessor 126 which is electrically coupled to a bus interface 128 followed by a hardware interface 130 and a signal conditioner 132. The bus interface 123 decodes the address data and control data from the microprocessor 126 to generate signals for the microprocessor 126 to access various registers and a latches of the bus and hardware interface electronics.

The bus interface 128 also conditions data from the hardware interface 130 and provides isolation of the microprocessor 126 from the latter. The hardware interface 130 holds the signals stable until updated from either the microprocessor 126 or the system hardware. It also generates signals from the load cell 26 and pressure level signals from the actuator 65 for a fixed time period before transferring that data to the microprocessor 126. Finally, the hardware interface 130 also counts pulses from the shaft encoder 66.

The function of the signal conditioner 132 is to adjust voltage levels, to buffer and boost drive signals for the relays and to filter signals. For example, signals destined for the servo valve 78 which are generated by the computer 126 and conditioned by the interfaces are pulse width modulated. The signal conditioner 132 converts the signals to a current proportional to the pulse width. The converted current is then used to drive the servo valve 78. In addition, force pressure signals in the form of voltages are converted by the signal conditioner 132 to frequency sent to the hardware interface 130. The signal conditioner 132 includes line drivers to boost the drive capability of binary signals sent to the interfaces and line receivers to wave shape binary signals sent from the interfaces. Finally, the

signal conditioner 132 includes optical isolating circuits to isolate from the rest of circuitry power sensors used to detect whether or not power is being applied to the motor 114 and dump valve 116.

Operation of the exercising apparatus involves the computer under control of a software program first entering a calibrate mode on initial powering-up of the system. The computer or microprocessor 136 then forces the actuator 65 to rotate in a clockwise direction until the central limit switch 63 is closed, thereby providing a signal which gives the computer 126 a datum point so that it can locate the angular position of the member 14. The actuator shaft is then rotated aproximately 25° in a counter-clockwise direction at which point the computer or microprocessor 126 checks the pressure levels in the actuator 65 to ascertain whether the hydraulic fluid is pressurized. The microprocessor 126 also causes offsets to be adjusted in order to compensate for shifts in the zero level of the circuitry, any servo valve offset and for weight in the actuator shaft in the event it is tilted from a horizontal position.

The program then causes the syustem to enter into an idle mode inwhich data may be entered into the microprocessor determining the type of exercise to be engaged in addition to changes in previously entered

data. The system then receives input data which may include the number of repetitions, the initial angle, the final angle, the required velocity, the minimum force below which the arm 14 will stop, whether the force to be applied is concentric or eccentric or a combination of the two, and possibly the duration of the exercise. Once the parameters are entered the arm 14 moves to a selected initial angle and cycles through the exercise routine. The exercise routine may be a constant angle or isometric exercise, a constant velocity exercise, a constant force exercise or a constant power exercise.

The microprocessor unit is a standard micro computer which contains a central processing unit, a memory, a diskette interface, a video display interface and a bus/card cage/power supply. Any one of a number of commercially available general purpose micro computers may be employed. The servo valve employed is manufactured by Koehring of Detroit, Michigan, and is an electro-magnetically activiated proportional valve which controls the amount of flow and the direction of the flow by the magnitude and plurality of current through its electro-magnetic winding.

It will be obvious to those skilled in the art that variations from the above-described system are obvious such as utilizing a potentiometer in place of an optical shaft encoder or utilization of a different system of

signal procesing altogether. It is considered that the signal conditioning and interface electronics given the functions desired to be performed will be obvious to the ordinary skilled technician.

Other variations, modifications and departures lying within the spirit of the invention and the scope as defined by the appended claims will be obvious to those skilled in the art.

CLAIMS:

1. A multi-mode exercising apparatus, comprising:

(a) an exercising member (14);

(b) a rotary actuator (65) coupled to said exercising member for controlling movement of said member in response to fluid flow therethrough;

(c) servo valve means (78) coupled to said actuator for controlling fluid flow through said actuator (65) in response to an input electrical signal;

(d) a hydraulic pump (112) for pressurizing said fluid;

(e) motor means (114) for driving said pump;

(f) a reservoir (110) for storing said fluid;

(g) means for monitoring the angular position of said actuator;

(h) load cell means (26) coupled to said member (14) for providing a signal proportional to the magnitude of force applied to said member;

(i) microprocessor (126) means for controlling the input electrical signal to said servo valve (78) in response to the signal from said load cell, the angular position of said actuator (65), program means stored in said microprocessor and calibration data.

2. A multi-mode exercising apparatus as defined in claim 1, further including a dump valve for shunting fluid flowing out of the pump into said reservoir.

3. A multi-mode exercising apparatus as defined in

claim 2, further including dump valve switch means for controlling power supplied to said dump valve.

4. A multi-mode exercising apparatus as defined in claim 1, comprising means for sensing actuator fluid pressure to provide signals whose differential is proportional to the external torque applied to said actuator by said member.

5. A multi-mode exercising apparatus as defined by claim 1 wherein said monitoring means is an optical shaft encoder for providing signals indicative of the angular velocity, position and direction of rotation of the actuator.

6. A multi-mode exercising apparatus as defined by claim 1 further including limit switch means for controlling power applied to said motor means in response to rotation of said actuator to pre-selected limits of rotation.

7. A multi-mode exercising apparatus comprising means for sensing the application of power to said dump valve and means for sensing the application of power to said motor.

8. A multi-mode exercising apparatus comprising:

(a) an exercising member;

(b) a rotary actuator coupled to said exercising member for controlling movement of said member in response to fluid flow therethrough;

(c) servo valve means coupled to said actuator for controlling fluid flow through said actuator in response to an input electrical current;

(d) a hydraulic pump for pressurizing said fluid;

(e) motor means for driving said pump;

(f) a reservoir for storing said fluid;

(g) a dump valve for shunting fluid flowing out of said pump into said reservoir;

(h) means for sensing actuator fluid pressure in order to provide signals the differential of which is proportional to torque applied to said actuator by said member;

(i) an optical shaft encoder for providing signals indicative of the angular velocity, position and direction of rotation of said actuator;

(j) limit switch means for controlling power applied to said motor means in response to rotation of said actuator to pre-selected limits of rotation;

(k) dump valve switch means for controlling power aplied to said dump valve;

(l) load cell means coupled to said member for providing a signal proportional to the magnitude of force applied to said member;

(m) means for sensing the application of power to said dump valve;

(n) means for sensing the application of power to said motor;

(o) over-ride switch means manually operable for controlling power to said motor means;

(p) microprocessor means for:

(i) controlling operation of said dump valve switch means in response to program means stored in said microprocessor and input data including calibration data, actuator fluid pressure levels, signals from said optical shaft encoder, signals from said load cell means, said motor sensing means, said dump valve sensing means, the condition of said limit switch means;

(ii) controlling power applied to said motor means in response to program means stored in said microprocessor and input data including calibration data, actuator fluid pressure levels, signals from said load cell means, said motor sensing means, the condition of said limit switch means, and the condition of said over-ride switch means; and

(iii) providing the input electrical signal to said servo valve, the magnitude of which is variable in response to program means

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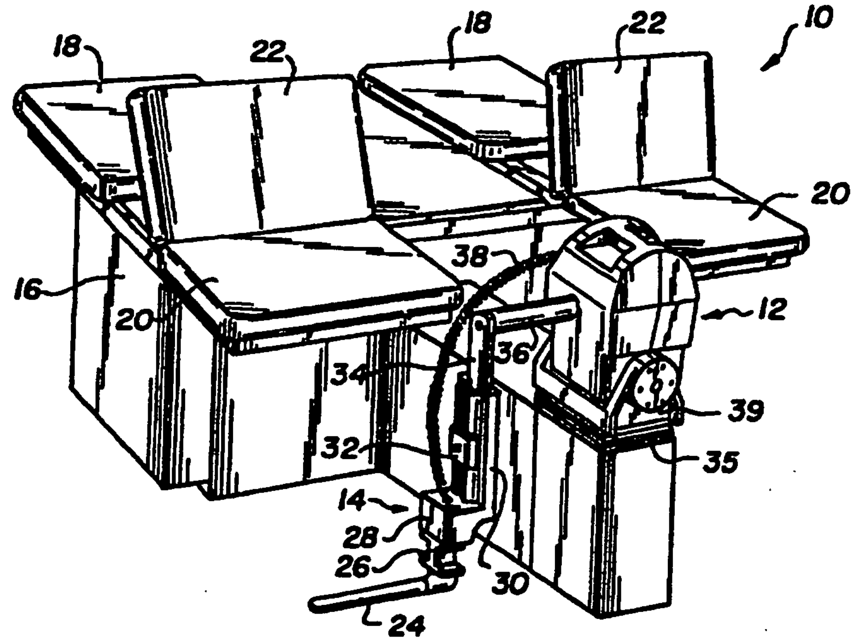
Fig. 1.



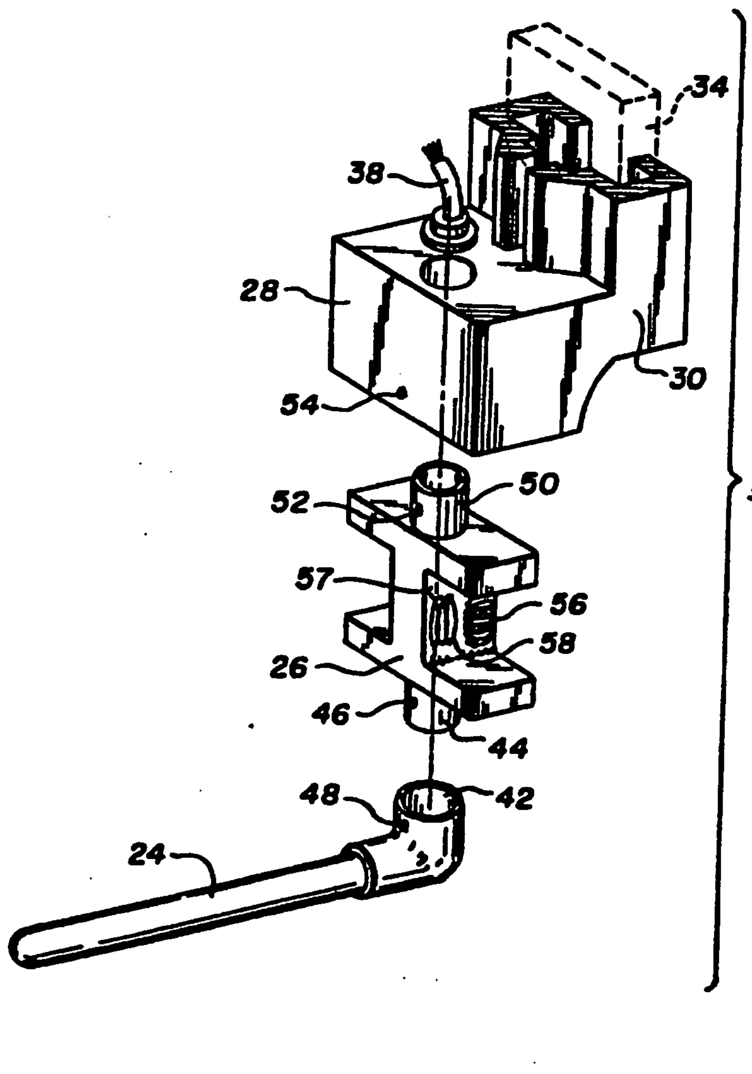


Fig. 2.

Fig.3.

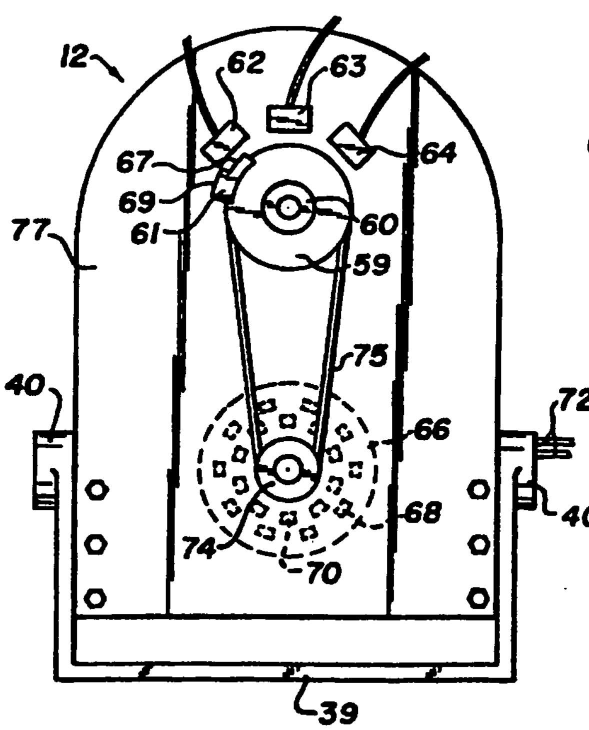


Fig.4.

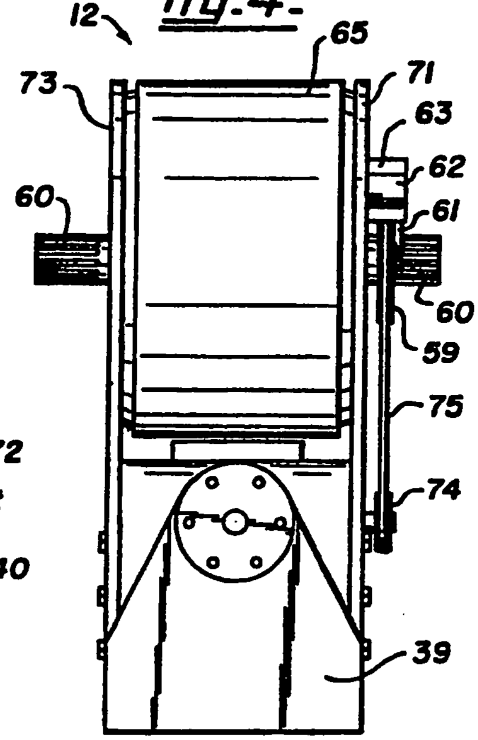
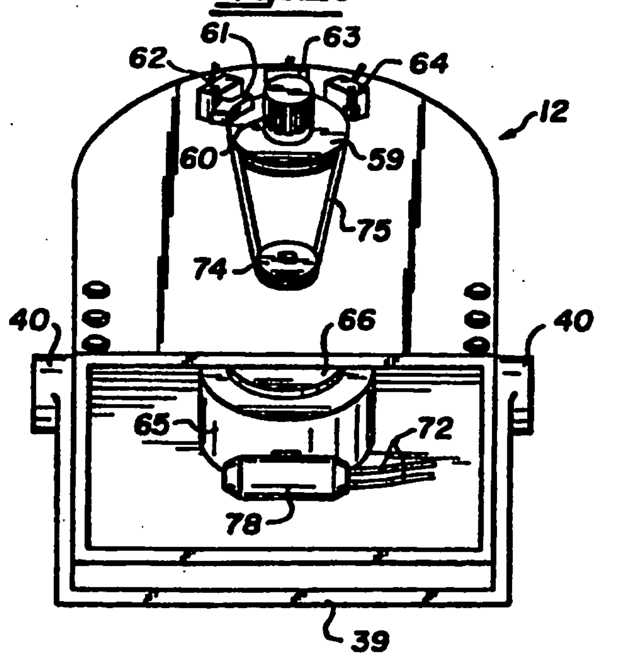
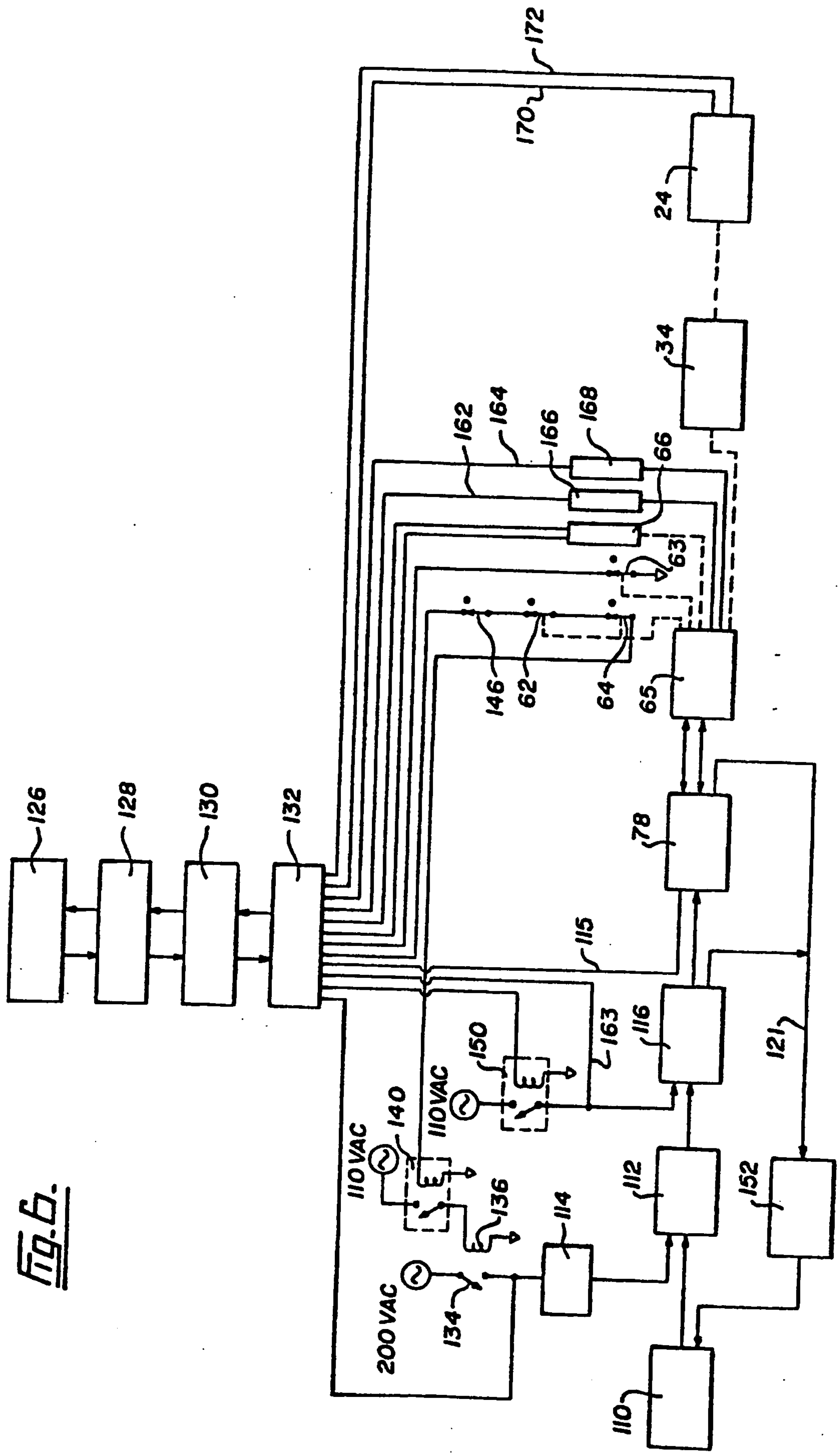


Fig.5.

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163
116
150
110VAC
110VAC
140
136
114
112
152
121
200VAC
134
110

Fig.6.

European Patent Office

EUROPEAN SEARCH REPORT.

0095832
Application number

EP 83301887.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	GB - A - 2 086 738 (ARIEL) * Abstract; claims; fig. 1,3 * --	1,8	A 63 B 21/00 G 01 L 5/02
A	US - A - 3 400 793 (NORRIS) * Claims; fig. 1-4 * --	1,8	
A	WO - A1 - 80/308 (STORV-RETA SPORT AB) * Abstract; fig. 1,3,4 * --	1,8	
D,A	US - A - 3 465 592 (PERRINE) * Abstract; fig. 1,8 * --	1,8	
D,A	US - A - 3 784 194 (PERRINE) * Abstract; fig. 1,11 * --	1,8	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A	FR - A - 2 144 958 (CUINER) * Totality * --	1,8	A 63 B 21/00 A 63 B 23/00 A 63 B 69/00 A 63 G 33/00 G 01 L 5/00
A	US - A - 3 495 824 (CUINIER) * Abstract; fig. 5 * --	1,8	
A	US - A - 4 144 568 (HILLER) * Abstract; fig. 1,2 * --	1,8	
A	US - A - 4 141 248 (BARGENDA) * Fig. 1,2; column 3, lines 21-49 * ----	1,8	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	22-07-1983	SCHÖNWÄLDER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category

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